

CHARACTERIZATION OF E-WASTE : RARE EARTH ELEMENT IDENTIFICATION

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ABSTRACT

Rare Earth Element (REE) or rare earth metal is one of a set of seventeen chemical elements in the periodic table. Rare earth element are widely used in many consumer electronics products such as smartphones, led monitor, powerful magnets in electric drive motors and etc. This research describes the study of the coating powder leaching from computer monitor scraps to obtain liquor which can be treated by hydrometallurgical techniques to extract the metals. Television(TV) tubes and computer monitors exist as coating powder that contain some rare earth elements(REEs). The recovery of the REEs from electronics scraps is very important in lieu of the economic and concerns. Leaching is a method of separation between solid and liquid. To separate the components, acid solvents such as nitric acid, hydrochloric acid, and sulphuric acid can be used. The results of this study pointed out the technical viability of the recovery of the metals. The coating powder used in this study was obtained by manually scraping the inner surfaces of computer monitor. Sulphuric (H_2SO_4), nitric acid (HNO_3) and hydrochloric (HCl) acids will be used in the leaching experiments. All solutions are analytical grade reagents and diluted with distilled water. The extract sample will be characterized by X-ray diffractometer. From the X-ray diffractometer, the data shows that LCD contain large value of indium. The conclusion that can be made from this study is for leaching process to extract rare earth elements, hydrochloric acid is the best solvent that can be used. Besides, in order to make sure the leaching process is effective, higher molarity of acid solvent is needed.

Key words: Environmental, Hydrometallurgy, Leaching process, Rare earth element, X- ray diffraction

ABSTRAK

Logam nadir bumi adalah salah satu daripada satu set tujuh belas unsur-unsur kimia dalam jadual berkala. Unsur nadir bumi banyak digunakan dalam banyak produk elektronik pengguna seperti telefon pintar, membawa monitor, magnet berkuasa di motor pemacu elektrik dan lain-lain. Kertas kerja ini menerangkan kajian tentang larut lesap serbuk salutan dari komputer monitor terbuang untuk mendapatkan cecair yang boleh dirawat dengan teknik hidrometalurgi untuk mengekstrak logam. Televisyen (TV) tiub dan monitor komputer wujud dalam serbuk salutan yang mengandungi beberapa unsur-unsur nadir bumi. Pemulihan unsur nadir bumi dari sisa elektronik adalah sangat penting dalam sektor ekonomi. Larut lesap adalah kaedah pemisahan antara pepejal dan cecair. Untuk memisahkan komponen, pelarut asid seperti asid nitrik, asid hidroklorik, dan asid sulfurik boleh digunakan. Hasil kajian ini menunjukkan daya maju teknikal dalam pemulihan logam. Serbuk salutan yang digunakan dalam kajian ini diperolehi secara manual dengan mengikis permukaan dalaman komputer monitor. Sulfurik (H_2SO_4), asid nitrik (HNO_3) dan hidroklorik asid (HCl) akan digunakan dalam eksperimen larut lesap. Semua larutan adalah gred reagen yang saintifik dan akan dicairkan dengan air suling. Sampel ekstrak akan dianalisa menggunakan X-ray diffractometer. Dari data yang diperolehi dari diffractometer X-ray, ia menunjukkan bahawa LCD mengandungi jumlah indium yang sangat tinggi. Kesimpulan yang boleh dibuat daripada kajian ini adalah, untuk proses larut lesap untuk mengeluarkan unsur-unsur nadir bumi, asid hidroklorik adalah pelarut terbaik yang boleh digunakan. Selain itu, bagi memastikan proses larut lesap adalah berkesan, kepekatan asid pelarut yang tinggi diperlukan.

Kata kunci: Alam Sekitar, Hidrometalurgi, Proses Larut Lesap, Unsur Nadir Bumi, Pembelauan Sinar-X

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LIST OF ABBREVIATIONS

| | |
|-----------|--|
| t | <i>time(s)</i> |
| D | <i>diffusivity($m^2 s^{-1}$)</i> |
| X | <i>distance of diffusion(m)</i> |
| C | concentration of the solute |
| θ | <i>angles of incidence</i> |
| d | <i>distance between atomic layers in a crystal</i> |
| λ | <i>wavelength of the incident X-ray beam</i> |
| n | <i>integer</i> |

LIST OF ABBREVIATIONS

| | |
|-----|----------------------|
| NIB | Neodymium Iron Boron |
| REE | Rare Earth Elements |
| REM | Rare Earth Magnet |
| REO | Rare Earth Oxide |
| XRD | X-Ray Diffraction |

1 INTRODUCTION

1.1 Background

Rare Earth Element (REE) or rare earth metal is one group of 17 chemical elements in the periodic table, particularly the lanthanides series, scandium and yttrium (Connelly, 2005). Scandium and yttrium are also considered as rare earth elements because they are always found in the same ore deposits as the lanthanides and exhibit similar chemical properties. The 17 REEs are found in all REE deposits but their distribution and concentrations vary. They are referred to as ‘rare’ because it is not common to find them in commercially viable concentrations. Significantly it is difficult to identify the physical and chemical properties as well as characteristics of the rare earth elements due to their near similarity (Gupta, C.K, & Krishnamurthy, 2005)

| | | | | | | | | | | | | | | | | | | | | | | | |
|--|----|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----------------|--|--|--|--|--|
| Rare Earth Elements | | | | | | | | | | | | | | | | | | by Geology.com | | | | | |
| H | | | | | | | | | | | | | | | | | He | | | | | | |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne | | | | | | |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar | | | | | | |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr | | | | | | |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe | | | | | | |
| Cs | Ba | La-Lu | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn | | | | | | |
| Fr | Ra | Ac-Lr | Rf | Db | Sg | Bh | Hs | Mt | | | | | | | | | | | | | | | |
| Lanthanides | | | | | | | | | | | | | | | | | | | | | | | |
| La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu | | | | | | | | | | | | | | | | | | | | | | | |
| Actinides | | | | | | | | | | | | | | | | | | | | | | | |
| Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr | | | | | | | | | | | | | | | | | | | | | | | |

Table 1 Rare Earth Element In Periodic Table

There are two categories of rare earth element which are light rare earth and heavy rare earth

| Light Rare Earths | Heavy Rare Earths |
|---|--|
| <ul style="list-style-type: none"> • Lanthanum (La) • Cerium (Ce) • Praseodymium (Pr) • Neodymium (Nd) • Samarium (Sm) | <ul style="list-style-type: none"> • Europium (Eu) • Gadolinium (Gd) • Terbium (Tb) • Dysprosium (Dy) • Holmium (Ho) • Erbium (Er) • Thulium (Tm) • Ytterbium (Yb) • Lutetium (Lu) • Yttrium (Y) |

Table 2 Types of Rare Earths

1.2 Motivation and statement of problem

Rare earth element are used in many electronics products and gadgets such as smartphones, led monitor, powerful magnets in electric drive motors and etc. Eventhough rare earth element (REEs) is present in relatively large amount in the earth's crust, REEs rarely come in concentrated forms,hence infeasible to mine. According to (Castor & Hendrick, 2003), China is the main supplier for rare earth element (REEs) globally. For the Chinese, their mining areas concentrated in Bayan Obo, Weishan and Mouniping. In 2003, China have supplied 90000 metric tonnes of rare earth element represents world's rare earth production for about 97% (Gowing & Matt, 2011).As rare earth element is widely used in high technology application, there are concerns that in coming years,the demand of these rare earth elements is more than what the Chinese can supply (York, Geoffrey, & Bouw, 2011). Furthermore,there are also indications that China had will decrease the rare earth export. (Hollins, 2010). By 2015, it has been predicted that China will not export rare earth elements anymore. This situation has caused an increase of interest among big companies from all over the world in production and recycling of rare earth elements.

Leaching is the extraction process involving solid and liquid. In leaching process, liquid will act as diluents while solid will be a composite solid whereby the separation posed a high degree of difficulty. According to (Perry's), leaching comprised of two types

namely is percolation (filtration) and disperse solid into liquid. The mechanism that present in leaching is between simple physical solutions by chemical reaction. Leaching rate can be affected by solvent concentration, reaction temperature, reaction time, liquid to solid ratio, and also stirring speed during mixing between solvent and rare earth. In leaching, transport process will occur between solvent and the surface of element. Leaching mechanism of rare earth is ion exchange between positive-ion in solution and the surface of rare earth material

Solvent selection criteria includes among others high saturation limit and selectivity for the extraction of the solute, must be able to produce high quality extracted product, low viscosity, low flammability and toxicity, low surface tension and low density. Most of the solvent used in leaching is acidic such as sulfuric acid and hydrochloric acid (Martins T. S., 2005). However, sulfuric acid will release sulfur dioxide (SO_2) and hydrogen fluoric (HF) which are difficult to be recycled and environmentally unfriendly. To mitigate this, other more benign chemical such as ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, HCL- AlCl_3 and NH_4NO_3 may be used

1.3 Objectives

The objectives of this research are:

To study the characterization of the coating powder leaching from e-scrap aiming at obtaining liquor which can be treated through metallurgical techniques to purify the metals. The parameters investigated will be leaching agent, acid/sample ratio, time of acid leaching, solids percentage and temperature of leaching.

1.4 Scope of this research

The following are the scope of this research:

In this leaching process, the rare earth elements from electronic waste will be used which is liquid crystal display (LCD) while the solvent (acid solution) used is such as hydrochloric (HCl), nitric acid (HNO₃) and sulphuric acid (H₂SO₄). The rare earth elements will be leach with the acid solvents for three steps leaching. The acid is used to extract rare earth metal from the LCD. The leaching is conducted by mixing the meshing LCD and the solvent. The method used for data analysis is x-ray diffraction (XRD). In the XRD, the rare earth metal will be analyze in solid phase. From the data collected, determination of the concentration of the rare earth metal that loss through the leaching process is obtain. The time duration for this research is about 3 weeks until the optimum of the rare earth meal is extracted from the liquid crystal display (LCD).

1.5 Main contribution of this work

Nowadays rare earth materials are used in many more products than is generally understood. Their uses are almost too numerous to list, but the major uses include ultra strong magnets for electric motors, advanced batteries, and phosphors for fluorescent lighting and display panels. Solid state laser systems, phosphors used in fluorescent lighting and plasma flat panel displays, optical fiber communications, and satellite communications all rely on rare earth materials.

Ultra strong (neodymium-iron-boron) magnets were discovered in the 1980s. More than twice as strong as previously known magnets, this touched off a revolution in miniaturizing electronic devices. Rare earth magnets lie at the heart of many of the consumer electronic products that have become so familiar in recent years, including: cell phones, laptop computers, small hard drives, and many personal electronic devices. Rare earth element are quite important to efforts to produce clean energy, especially LCD where large amounts of rare earth metals are used in the display panel.

Therefore, the recycling of the rare earth element is really worthwhile since there are really in highly demands.

1.6 Organisation of this thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 2 provides a description of the applications and general features rare earth elements. A general description on the characteristics of rare earth element, as well as the uses of rare earth elements. This chapter also provides a brief discussion of the advanced experimental techniques available for recycling and also leaching process of the rare earth elements, mentioning their applications. A summary of the previous experimental work on recovery of rare earth element is also presented. A brief discussion on the scale-up methods is also provided..

Chapter 3 gives a review method and procedure of the experiment.

Chapter 4 gives the expected result and discussion of the experiment.

Chapter 7 draws together a summary of the thesis and outlines the future work which might be derived from the model developed in this work

2 LITERATURE REVIEW

2.1 Overview

The most important reason in increasing of interest in recycling rare earth metals or elements is the highly demand of rare earth element in the electronic industries. In 2012, China had produced about 85 percent and consumed 70 percent of world's rare earth element, and reported in a that it will reduce production. Japan has no rare earth metal production capacity, it only consumed 15 percent of the global yearly production mainly by importing from China.

It is worth noting that it is not the rarity of rare earth metals that is the challenge, but rather finding it in commercially viable ore concentrations. (LeBlanc, 2013) A large rare earth ore concentration has been found on the ocean floor that may be 20 to 30 times as large as that of China, but the extraction cost would be really high,

So, countries which consume rare earth minerals need to depend on China. By recycling, countries can help meet their demand of rare earth minerals. The recycling of rare earth metals can make metal prices down. Other important reason for recycling rare earth elements is the high possibility of serious environmental damage related to the mining and refining of rare earth metals. Beside the risk of radioactive tailings, rare earth minerals refining need the use of toxic acids (LeBlanc, 2013)

The recycling rates for rare earth metals is about 1 percent, only a very little of what could be reused. Most of the applications that uses rare earth elements is such as computer hard drives, cell phones, fluorescent lighting, REE can be recovered and reused, even though plenty of e-waste material must be recycled to generate a small amount of rare earth metals. For example, 300 tons of circuit boards can produce only 150 grams of rare earth metals through a smelting process.

In future, technologies for successful rare earth metal recycling continue to developed, while some product manufacturers had decided to eliminate their use of these materials. At the same time, there is also interest in product design to support recycling - allowing for more cost effective recycling. (LeBlanc, 2013)

2.1.1 Rare Earth Elements

The rare earth element (REEs) are group of 17 elements consist of lanthanides, scandium and yttrium. Among the REEs, promethium (Pm) is the most rare, however some of the REEs are not really rare and occur spread in a many types of forms (Greenwood, N.M, & Earnshaw) (Tyler, 2004).The infinite applications of the REEs are based on their particular properties, for the most is their spectroscopic and magnetic properties (Martins, S, Isolani, & Celso, 2005). REEs have been mainly used in agriculture, electronics, superconductors, nuclear medicine, automobile industry, special inks – which is used in radar invisible airplanes, X-ray screens, high intensity mercury vapour light bulbs, neutron scintillators, charged-particle detectors and optical memory reading systems (Maestro, 1995) (Sanchez, 2001). Rare earth elements has very specific and versatile metallurgical, chemical, catalytic, electrical, magnetic and optical properties (Geology.com). Table 3 shows the summary of unique properties of Rare Earth Elements.

| | |
|----------------------|--|
| Chemical | Has unique electron configuration |
| Catalytic | Oxygen storage and release |
| Electrical | High conductivity |
| Magnetic | High magnetic anisotropy and large magnetic moment |
| Optical | Fluorescence, high refractive index |
| Metallurgical | Efficient hydrogen storage in rare earth alloys |

Table 3 Unique Properties of Rare Earth Elements

Table 4 shows the types of Rare Earth Element with their unique properties

| REE | Catalytic | Magnetic | Electrical | Chemical | Optical |
|-------------------|-----------|----------|------------|----------|---------|
| Lanthanum (La) | X | | X | X | X |
| Cerium (Ce) | X | | X | X | X |
| Praseodymium (Pr) | | X | X | X | X |
| Neodymium (Nd) | X | X | X | | X |
| Samarium (Sm) | | X | | | |
| Europium (Eu) | | | | | X |
| Gadolinium (Gd) | | X | | | X |
| Terbium (Tb) | | X | | | X |
| Dysprosium (Dy) | | X | | | X |
| Erbium (Er) | | | | | X |
| Yttrium (Y) | | | | | X |

Table 4 Types of Rare Earth Element with Their Unique Properties

The technological development of the last 10 years in the differing sectors of the electronic industry has stimulated the replacement of out-of-date gadgets. As a result, there is an increasing number of disposal of out-of-date computers and other electronic equipments into landfill sites all over the world.

2.1.2 Rare Earth Applications

Every types of Rare Earth Element(REEs) have their own application and uses (Ernst & Young, 2011)

| REE | Uses |
|---------------------|---|
| Scandium | Metal alloys for the aerospace industry |
| Yttrium | Ceramics; metal alloys; lasers; fuel efficiency; microwave communication for satellite industries; color televisions; computer monitors; temperature sensors. Used in targeting and weapon systems and communication devices. |
| Lanthanum | Batteries; catalysts for petroleum refining; electric car batteries; high-tech digital cameras; video cameras; laptop batteries; X-ray films; lasers. Used in communication devices. |
| Cerium | Catalysts; polishing; metal alloys; lens polishes (for glass, television faceplates, mirrors, optical glass, silicon microprocessors, and disk drives). |
| Praseodymium | Improved magnet corrosion resistance; pigment; searchlights; airport signal lenses; photographic filters. |
| Neodymium | High-power magnets for laptops, lasers, fluid-fracking catalysts. Used in guidance and control systems, electric motors, and communication devices. |
| Promethium | Beta radiation source, fluid-fracking catalysts |
| Samarium | High-temperature magnets, reactor control rods. Used in guidance and control systems and electric motors. |

| | |
|-------------------|--|
| Europium | Liquid crystal displays (LCDs), fluorescent lighting, glass additives. Used in targeting and weapon systems and communication devices. |
| Gadolinium | Magnetic resonance imaging contrast agent, glass additives. |
| Terbium | Phosphors for lighting and display. Used in guidance and control systems, targeting and weapon systems, and electric motors.. |
| Dysprosium | High-power magnets, lasers. Used guidance and control systems and electric motors. |
| Holmium | Highest power magnets known. |
| Erbium | Lasers, glass colorant |
| Thulium | High-power magnets |
| Ytterbium | Fiber-optic technology, solar panels, alloys (stainless steel), lasers, radiation source for portable X-ray units |
| Lutetium | X-ray phosphors |

Table 5 Types of Rare Earth Element and Its Uses

Rare Earth Element also have their own specific application which widely used in electronic product (Fogler & Tim, 2011).

| Application | Description |
|--------------------|--|
| Permanent Magnets | They are in high demand due to their strength, heat resistance and ability to maintain their magnetism over very long periods of time. Magnets made from rare earth elements, such as neodymium, praseodymium, and dysprosium are the strongest known permanent magnets. |

| | |
|--------------------------|--|
| Rechargeable Batteries | Rechargeable batteries (NiMH) made from lanthanum, cerium, neodymium and praseodymium (combined with nickel, cobalt, manganese and/or aluminum) are used in car batteries in hybrid electric vehicles, electronic devices and power tools |
| Auto Catalysts | Lanthanum and Cerium are used in the manufacture of catalytic converters which convert the pollutants in engine exhaust to non-toxic compounds |
| Fluid Cracking Catalysts | Fluid cracking catalysts, which contain lanthanum and cerium, are used in the refining of crude oil. |
| Polishing Powders | Cerium Oxide polishing powder is one of the best polishing materials. It is used for polishing glass, lenses, CRTs, jewels, silicon chips, TV screens and monitors. |
| Glass Additives | Cerium reduces transmission of UV light and Lanthanum increases the glass reflective index for digital camera lenses. |
| Phosphors | Europium, terbium and yttrium are REEs used extensively in the electronics industry to manufacture LCDs and colour TVs. Used as phosphors they enable colour changes as electrical currents are transmitted through them. |

Table 6 Rare Earth Application

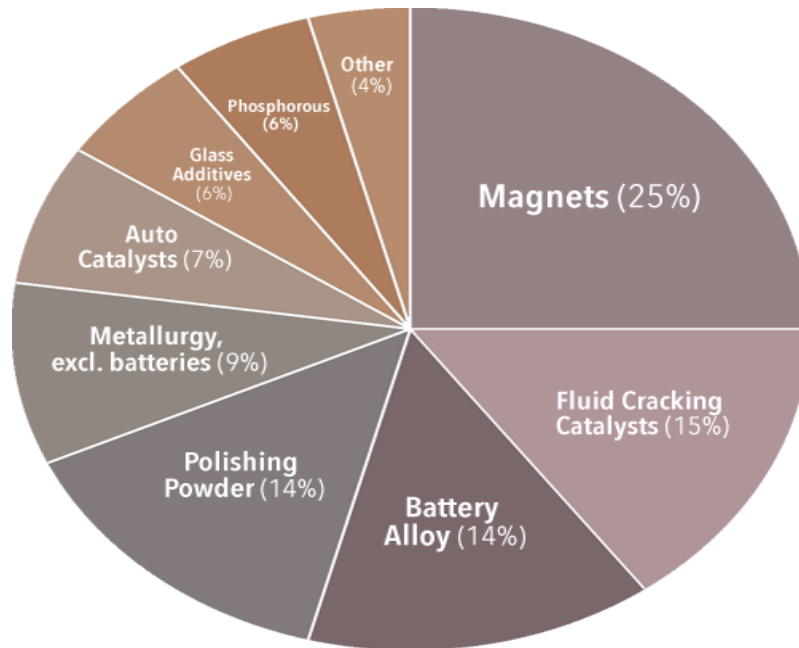


Figure 1 Rare Earth Element Product Usage by Industry

2.1.3 Liquid Crystal Display (LCD)

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly (Arpaci-Dusseau, RemziH, & C, 2014). Liquid crystal Display (LCD) is divided into two components which is cold cathode fluorescent lamps and light emitting diodes. They are used in the LCD panel as the backlight unit. In the structure of LCD, LCD glass (panel), various optical films, and backlight are arranged in laminar structure. The differences can be seen in the production of LCD of television and LCD of computer monitor where the location of lamp behind the screen is different. For the LCD TV the lamp are arranged in a row in the back of the module while in monitor lamp it is placed at each long edges of the module behind the panel and “light guide” is used to redirect the lightning towards the panel. ITO is the component of rare earth element that located in the LCD panel. In figure 2 below, the structure of the key components in a panel and LCD was put in between two glass panels is shown. The recovery of the REEs from the electronics scraps (e-scrap) and other metals is very important due to economic and environmental issues (Kingsnorth & J., 2010).

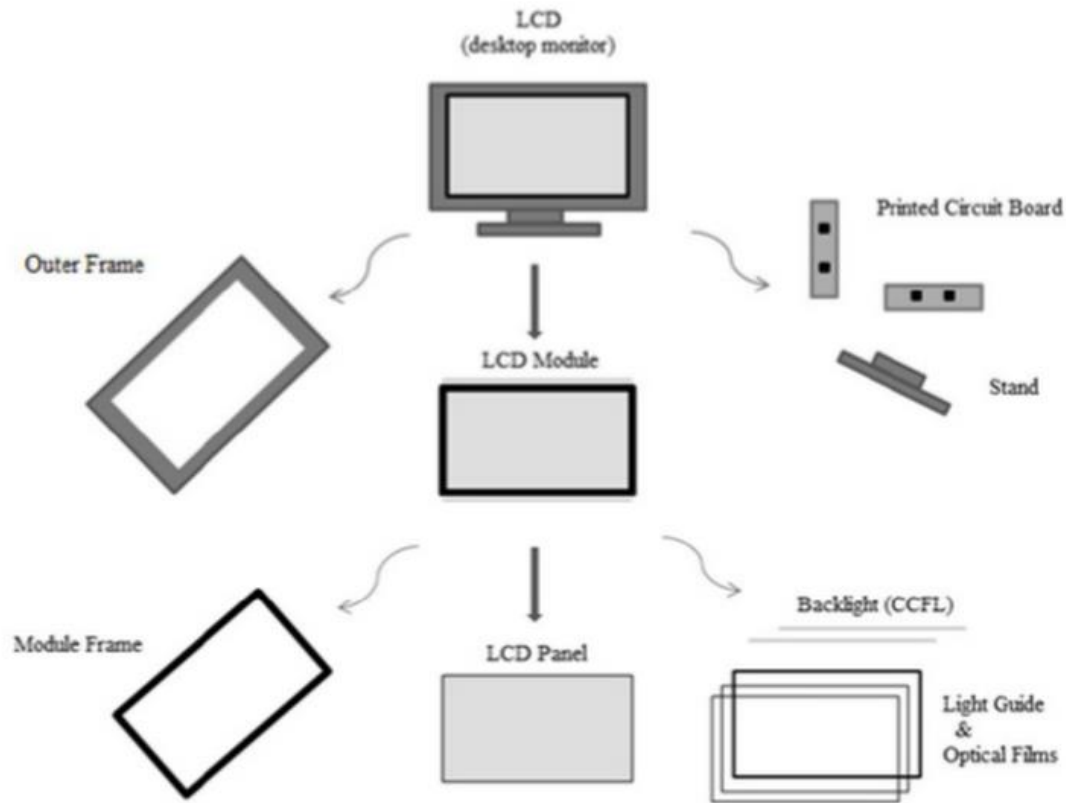


Figure 2 Component of LCD and Its General Structure

2.1.4 Europium

Eventhough Europium is one of the most important light rare earth elements (USGS definition) which is more abundant than the heavy rare earths, it is been classified as one of the most expensive rare earth elements and also has been categorized as one of the critical rare earths (Buchert & e.V., 2011). Shortages have been predicted with a high degree of probability (Schüler & Buchert, 2011). Because of high prices of europium and terbium, lighting and display systems represent one of the most economic rare earth applications (Buchert, Manhart, Bleher, & Pingel, 2012). Europium is usually used in phosphors, for example materials which can emit light when exposed to a light or electron source (Schüler & Buchert, 2011). It is different with the element phosphorus whose light emitting properties are down to a different phenomenon (Schüler & Buchert, 2011). To get phosphor materials, salt-like host lattices (matrices) are dotted with metal ions (e.g. Eu^{2+} or Eu^{3+}), which are act as activators of the dopants (Schüler & Buchert, 2011). Europium can produce a red or blue light depending on the

oxidation state (Schüler & Buchert, 2011). By combining the Eu^{2+} and Eu^{3+} in the phosphor application, it can yield a white light that is been used in compact fluorescent bulbs (Stewart, 2014). Europium is one of the most common rare earth that widely used as an activator in phosphors, followed by terbium, but it should be alert that the rare earths used in the phosphor matrices such as yttrium are more important in terms of absolute quantities used (Buchert, Manhart, Bleher, & Pingel, 2012). Activators are used in low concentrations of phosphor material (Schüler & Buchert, 2011). Even though Europium and other rare earths such as terbium, samarium, erbium, thulium, cerium and dysprosium are used in very small amount, their role in the respective application is important and there is a lack of suitable substitutes in the short term (Schüler & Buchert, 2011). Rare earths are used in most energy efficient lighting technologies, including compact fluorescent light bulbs (energy saving light bulbs), fluorescent tubes, LEDs, EL foils, plasma displays and LCD displays. This rare earths use to helps achieve good color qualities and higher energy efficiencies (Schüler & Buchert, 2011)

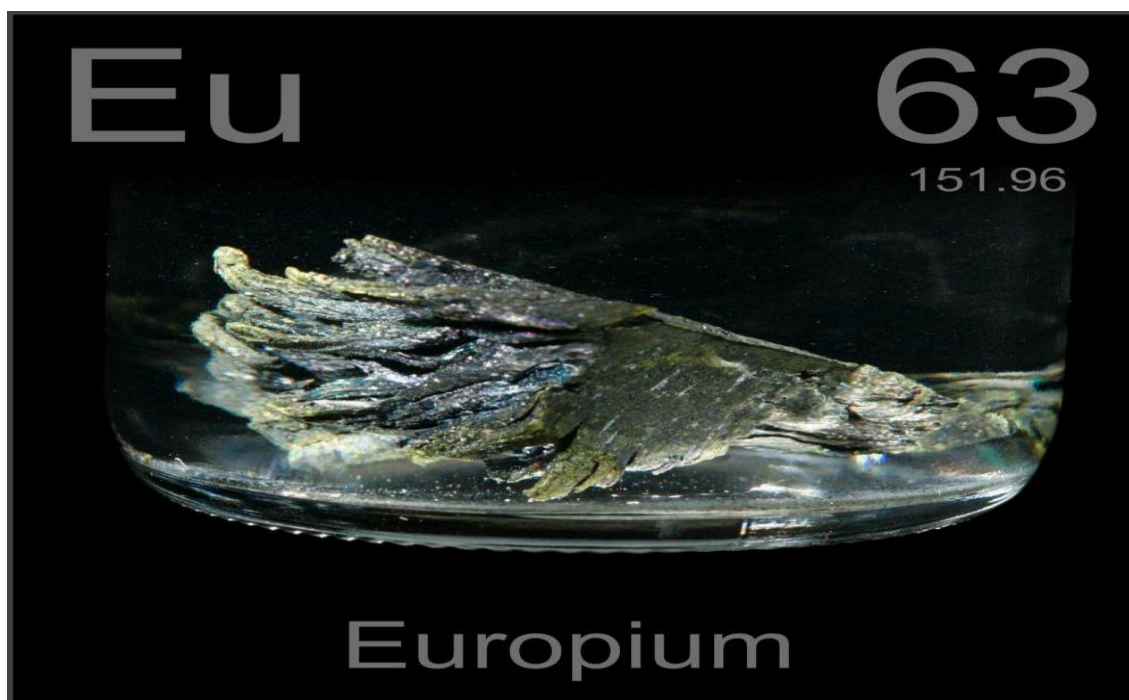


Figure 3 Europium

2.1.5 Recovery Of Rare Earth Element

(Morais, 2001) had stated that the recovery of europium from computer LCD uses sulphuric acid as the leaching agent. In this study, the Eu and Y solubilisation is 90 wt% and 95 wt.% respectively when conducted at 90°C, 2 hour of leaching, acid/sample ratio of 1000 kg/t and 40% solids. At 70°C, 1500 kg/t acid/sample ratio, 2 hour of leaching, and 40% solids, the solubilisation of both metals was 80wt%.

(Rabah, 2008) had stated that the recovery of europium from computer LCD will use a mixture of sulphuric/nitric acids as the leaching agent. At critical conditions for example autoclave digestion, at 125°C, 4 hour and 5 MPa using a mixture of sulphuric/nitric acids, the Eu and Y solubilisation is 92.8 wt% and 96.4 wt% respectively.

2.1.6 Separation Of Rare Earth Element

The separation of REE is very difficult due to its chemical properties. However, the REEs can be very easily replaced for one another making refinement to pure metal difficult (British Geological Survey, 2010). Hence, the separation of REE into two stages which are Extraction of Rare Earth Oxides (REO) from Monazite or xenotime and Purification of Rare Earth Oxides (REO)

Monazite is known as a reddish-brown phosphate mineral that contain REEs. There are four different type of monazite, which is monazite-Ce (Ce, La, Pr, Nd, Th, Y)PO₄, monazite-La (La, Ce, Nd, Pr)PO₄, monazite-Nd (Nd, La, Ce, Pr)PO₄ and monazite-Sm (Sm, Gd, Ce, Th)PO₄. In the other hand, xenotime is rare earth phosphate mineral. The major component of xenotime is yttrium orthophosphate (YPO₄). It will forms a solid solution series with chernovite-(Y) (YAsO₄) and may have trace impurities of arsenic, silicon dioxide and calcium. Monazite will be obtain from the milling process which is a process where valuable mineral material in the ore is separated from impurities. (Kidela Capital Group, 2011)

2.1.7 Extraction Of Rare Earth Elements

There are two chemical process route in extraction of REEs that can be performed. The two route are Acid Treatment and Caustic Soda Method. According to (British Geological Survey, 2011), extraction of REEs from monazite and xenotime will involves dissolution of the minerals in hot concentrated alkaline(caustic soda method) or acidic solutions (acid treatment).

2.1.8 Leaching

Leaching is the extraction between solid and liquid. In leaching process, liquid act as a diluents where as the solid usually was a composite solid where there is quite hard to separate the composite matter. Actually, rare earth element is one type of composite element. Leaching is a liquid-solid operation. The two phases are in intimate contact, the solute(s) can diffuse from the solid to the liquid phase, which causes a separation of the components originally in the solid. Solid-liquid extraction uses a solvent to remove a soluble fraction from an insoluble, permeable solid. (J.E.Cacace and G. Mazza, 2003)

Leaching process can be divided into two types. First is percolation which also known as filtration and second is disperse solid into liquid (Perry's). In leaching process, the mechanism that involved is between simple physical solutions by chemical reaction. Leaching rate can be changing by many factor which are solvent concentration, reaction temperature, reaction time, liquid to solid ratio, and also stirring speed during mixing between solvent and rare earth (Li, 2012)

The increasing of the extraction temperature increased the rate of extraction and reduced the extraction time by increasing the diffusivity (J.E.Cacace and G. Mazza, 2003).

Other than that, based on (J.E.Cacace and G. Mazza, 2003), the rate of extraction increases with a larger concentration gradient. It can also be improved by increasing the diffusion coefficient or reducing the particle size.

Smaller particle size reduces the diffusion distance of the solute within the solid and increases the concentration gradient, which increase the extraction rate. Since the path of solute to reach the surface is shorter, extraction time is reduced.